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13. ABSTRACT (*Maximum 200 words*)

This research program has dealt with atomic collision processes of interest for models of natural or man-made plasmas, such as electrical discharge devices, gas lasers, and atmospheric plasmas. Specific topics have included: (A) Electron-ion recombination of NO^+, O_4^+, and N_4^+ ions, preparation of data compilations on electron-ion recombination. (B) Experimental measurements of rates of neutral-stabilized electron-ion recombination. (C) Experimental measurements of recombination of positive with negative ions. (D) Experimental and theoretical work on ion-atom and ion-molecule elastic and reactive collisions, and laser-induced charge-transfer reactions.

14. SUBJECT TERMS

Electron-ion recombination. Plasma-afterglows. Ion-ion recombination. Ion-atom association. Drift-tube techniques. Photon-induced charge transfer.

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LABORATORY STUDIES OF ATOMIC COLLISION PROCESSES

Final Technical Report

by

Rainer Johnsen

Aug. 15, 91

U.S. ARMY RESEARCH OFFICE

Research Agreement No. DAAL03-87-K-0048

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I. Scope of the Research Program

The research program carried out under Research Agreement No. DAAL03-87-K-0048 has dealt with atomic collision processes of interest for models of natural or man-made plasmas, such as electrical discharge devices, gas lasers, and atmospheric plasmas. Specific topics have included plasma deionization processes, in particular electron-ion and ion-ion recombination processes an ion-atom interactions.

Several distinct experimental techniques were used in this work, in particular afterglows of microwave-generated or photoioinized plasmas, and ion drift tube methods.

Technical details and results of this work have been published in scientific journals or conference proceedings. References to published work are given in the sections on specific research topics.

II. Specific Research Topics

A. Dissociative recombination of electrons with molecular ions.

1. Our earlier work on recombination of NO^+ ions as a function of electron temperature was published during this report period. (Ref.1)

2. Our earlier work on recombination of O_4^+ ions as a function of electron temperature was published during this report period. (Ref.2)

3. A data compilation and critical review of electron-ion recombination data obtained by the microwave afterglow method was published. (Ref.3)

4. Experimental work was carried out on molecular band emissions resulting from products of N_4^+ recombination. The results have just been submitted for publication. (Ref.4)

B. Neutral stabilized electron-ion recombination

1. Experimental work was carried out on high-pressure recombination in helium gas to test theories of neutral-stabilized electron-ion recombination. This work has been published. (Ref.5)

2. A search for effects of electron localization on electron-ion recombination in cryogenic helium plasmas at a temperature of 4K has been carried out. This work is still in progress.

C. Recombination of positive with negative ions.

1. Subsequent to the development of suitable experimental methods, ion-ion recombination of molecular ions was studied in helium and argon gas in order to test theories on such processes. The results have been published. (Ref.6)

2. The recombination of Xe^+ with F^- ions and excimer emissions from the XeF^* product were investigated. The results have been published. (Ref.7)

D. Ion-atom and ion-molecule reactions

1. As a test of ion transport theory, the mobility of He^+ ions in helium was measured and the results were compared to theoretical calculations by L.A. Viehland using interaction potentials obtained from spectroscopic data. This work was published jointly with L.A. Viehland. (Ref.8)

2. A semi-empirical theory on ion-atom association reactions was developed and compared to experimental data on such reactions. The goal of this work was to provide a simple estimating formula that could be used to obtain rate coefficients for plasma models. Published (Ref.9)

3. Ion-molecule association reactions in HCN were studied experimentally. Published (Ref.10)

4. Very extensive work was performed to find evidence for laser-induced charge transfer of Ne^+ ions with He. It appears that cross sections for laser induced charge transfer are far smaller that had been expected from previous work. This work is still in progress.

Participating personnel:

R. Johnsen

B.K. Chatterjee (PhD 1988)

H.S. Lee (PhD 1990)

R. Tosh

Y.S. Cao

Publications during period from 04/01/87 to 6/30/91
(Reprints or preprints are available on request)

Journal articles:

1. "Electron temperature dependence of the recombination of electrons with NO^+ ions", J.L. Dulaney, M.A. Biondi, and R. Johnsen. Phys. Rev. A 36, 1342 (1987)

2. "Electron temperature dependence of the recombination of electrons with O_4^+ ions", J.L. Dulaney, M.A. Biondi, and R. Johnsen. Phys. Rev. A 37, 2539 (1988)

3. "Microwave afterglow measurements of the disscociative recombination of molecu lar ions with electrons", R. Johnsen, Int. J. Mass Spectr. and Ion Proc. 81 , 67 (1987)

4. "Recombination of N_4^+ ions with electrons", Y.S. Cao and R. Johnsen, submitted to J. Chem. Phys. in June 1991

5. "Neutral stabilized recombination in ambient helium gas", Y.S. Cao and R. Johnsen, J. Chem. Phys. 94, 5443 (1991)

6. "Ion-ion recombination studies in ambient helium and argon at atmospheric densi ties", H.S. Lee and R. Johnsen, J. Chem. Phys. 90, 6328 (1989)

7. " Recombination of Xe+ with F- ions in ambient helium" , H.S. Lee and R. Johnsen, J. Chem. Phys. 93, 4686 (1990)

8. " Mobility of helium ions in neon: Comparison of theory and experiment", R. Johnsen, R. Tosh, and L.A. Viehland, J. Chem. Phys. 92, 7264 (1990)

9. "An estimating formula for ion-atom association rates in gases", B.K. Chatterjee and R. Johnsen, J. Chem. Phys. 93, 5681 (1990)

10. "Clustering reactions of H_2CN^+ ions with HCN" , B.K. Chatterjee and R. Johnsen, J. Chem. Phys. 87, 2399 (1987)

Book chapters:

11. "Electron-ion, ion-ion, and ion-neutral interactions", R. Johnsen, in "Nonequilibrium effects in ion and electron transport", Edited by J. W. Gallagher, D.F. Hudson, E.E. Kunhardt, and R.J. van Brunt, (Plenum Press, New York and London, 1990)

12. "Recombination measurements in microwave plasma afterglows", R. Johnsen, in " Dissociative recombination: Theory, experiment, and applications", Edited by J.B. A. Mitchell, and S. L. Guberman (Word Scientific 1989)